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Statement of inventorship and of right to grant of a patent

The Patent Office
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1. Your reference
5276202/AM

2. Patent Application Number
accompanying application reference 5276202
9825954.2

3. Full name of the or each applicant
Metrixx Limited

4. Title of the invention
SIGNALLING SYSTEM

5. State how the applicant(s) derived the right from the inventor(s) to be granted a patent
By virtue of employment

6. How many, if any additional Patents Forms 7/77 are attached to this form?
NONE

11. I/We believe that the person(s) named over the page (and on any extra copies of this form) is/are the inventor(s) of the invention which the above patent application relates to.

Signature Beresford & Co
BERESFORD & Co
Date 26 November 1998

12. Name and daytime telephone number of person to contact in the United Kingdom
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Patents Form 7/77

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The Patent Office

Request for grant of a patent

The Patent Office
Cardiff Road
Newport
Gwent NP9 1RH

1. Your reference
5276202/AM

2. Patent Application Number
9825954.2

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

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Patents ADP number *(if known)* 7414105002.

If the applicant is a corporate body, give the country/state of its incorporation
Country: SCOTLAND
State:

4. Title of the invention
SIGNALLING SYSTEM

5. Name of agent
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Patents ADP number 1826001

6. Priority details

Country	Priority application number	Date of filing

Patents Form 1/77

7. If this application is divided or otherwise derived from an earlier UK application give details

Number of earlier of application | Date of filing

8. Is a statement of inventorship and or right to grant of a patent required in support of this request?

YES

9. Enter the number of sheets for any of the following items you are filing with this form.

Continuation sheets of this form	0
Description	31
Claim(s)	8
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Priority documents	N/A
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Statement of inventorship and right to grant of a patent *(Patents form 7/77)*	1(plus 1 copy)
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11. I/We request the grant of a patent on the basis of this application

Signature Beresford & Co Date 26 November 1998

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SIGNALLING SYSTEM

The present invention relates to a signalling system. The invention is applicable for use in a system for monitoring and/or controlling the cells of an industrial battery.

Industrial batteries comprise a number of rechargeable battery cells which can be electrically connected in various series and series-parallel combinations to provide a rechargeable battery having a desired output voltage. To recharge the battery, a current is passed through the cells in the opposite direction of current flow when the cells are working. There are many different types of battery cells available, but those most commonly used in industrial applications are lead acid battery cells, each of which provides 2 volts, and nickel-cadmium (Nicad) battery cells, each of which provides 1.2 volts.

The batteries are usually used as a back-up power supply for important systems in large industrial plants, such as off-shore oil rigs, power stations and the like. Since the batteries are provided as back-up in the event of a fault with the main generators, they must be constantly monitored and maintained so that they can provide power to the important systems for a preset minimum amount of time.

Many battery monitoring systems have been proposed which monitor the battery as a whole and provide an indication of the battery voltage. However, only a few systems have been proposed which can also monitor the individual cells which make up the battery. These systems use a number of monitoring devices, some of which are powered by the

battery cell or cells which they monitor and send status information indicative of the cell voltage back to a central battery monitoring system which monitors the battery as a whole.

However, since the cells are connected in series and since each cell monitoring device is powered by the cell which it is monitoring, the ground or reference voltage of each cell monitoring device is different. For example, in an industrial battery which has sixty lead acid cells connected in series, the negative terminal, i.e. the ground, of the fifth cell will be at a potential of approximately 8 volts and the positive terminal will be at a potential of approximately 10 volts, whereas the negative terminal of the seventh cell will be at a potential of approximately 12 volts and the positive terminal will be at a potential of approximately 14 volts. This has led to the common misconception in the art that the cell monitoring devices have to be electrically isolated from each other and from the central battery monitoring system.

In one known cell monitoring system, each cell is independently linked to its own electrically isolated input at the central monitoring system. The problem with this system is that a large number of connectors are needed to link the individual cell monitoring devices to the central monitoring system. Consequently, in practice, it is seldom used for permanent real-time monitoring of the battery cells.

In another known cell monitoring system, each cell monitoring device is serially linked to its neighbours in a daisy-chain configuration, either by using optical links between the monitoring devices or by using

transformers which have no DC path. The problem with this system is that to operate, each of the cell monitoring devices requires either an electrical to optical and an optical to electrical converter or a modulator and a demodulator, which makes them relatively expensive and inefficient since this additional circuitry requires more power from the cell.

There is therefore a need to provide a simple cell monitoring device which can monitor and report on the status of the cells of the battery, but which consumes minimal power from the cell which it is monitoring.

The inventor has realised that it is possible to overcome the problem of having the cell monitoring devices operating at different voltages using simple electronic components and that therefore, there is no need for electrical isolation between the individual cell monitoring devices and the central monitoring system.

The applicant has proposed a solution to this problem in PCT/GB98/00170 which uses a number of cell signalling devices, each to be powered by a respective one or more of the battery cells and a communications link connecting the cell signalling devices in a daisy chain configuration, and wherein each cell signalling device comprises a DC level shift circuit which is operable to receive signals transmitted from an adjacent cell signalling device, to shift the DC level of the received signals and to output the level shifted signals for transmission to the next cell signalling device. As suitable DC level shift circuits, the application proposes, among others, voltage comparators. However, the use of such voltage comparators to shift the DC level is not practical where there are large differences in

voltage levels between adjacent cell signalling devices or where there are a large number of cell signalling devices connected in series.

According to one aspect, the present invention provides a signalling system comprising first and second signalling devices, and wherein signals are transmitted from the first signalling device to the second signalling device by varying the impedance of an output terminal of the first signalling device and by detecting the variation of impedance in the second signalling device. By transmitting signals in this way, the signalling devices can be linked together without the need for electrical isolation between them. The signalling system can be used as part of a battery monitoring and/or control system which is used to monitor and/or control a plurality of series connected battery cells. In this case, since there is no need for electrical isolation between the signalling devices, the communication link can be a simple one-wire communication bus.

Preferably each of the signalling devices is able to receive communications from and transmit communications to the communication link so that they can communicate with, for example, the battery monitoring and/or control system. In which case, each cell signalling device can comprise an output terminal whose impedance can be varied in dependence upon a signal to be transmitted to an adjacent cell signalling device and sensing means for sensing the variation of an output terminal of another cell signalling device and means for regenerating the signal transmitted by that other cell signalling device.

Preferably, the output terminal comprises a switch, such as a MOSFET, and wherein each signalling device comprises

means for opening and closing the switch in dependence upon the signal to be transmitted. In this way, it is possible to vary the impedance of the output terminal from a high impedance value to a low impedance value with very little power consumption.

Preferably, each signalling device comprises a microcontroller for receiving signals transmitted from an adjacent signalling device so that it can recondition the transmitted signal for onward transmission to another cell signalling device. In this way, errors caused by the propagation of the signals through a number of signalling devices can be reduced.

The present invention also provides a cell signalling device for use in the above signalling system, comprising: a power input terminal connectable to the cell or cells which is or are to power the cell signalling device; an output terminal for connection to an adjacent cell signalling device via said communication link; means for varying the impedance of said output terminal in dependence upon a signal to be transmitted to said adjacent cell signalling device; an input terminal for receiving signals from another adjacent cell signalling device; and means for sensing, via said communication link and said input terminal, the variation of impedance of the output terminal of said another adjacent cell signalling device and for outputting a signal which varies in dependence upon the sensed variation of impedance.

The present invention also provides a signalling kit comprising a plurality of the cell signalling devices defined above. The kit may also comprise the communication link for connecting the cell signalling

devices in series.

The present invention also provides a signalling method comprising the steps of: providing first and second signalling devices; providing a communication link for connecting an output terminal of the first signalling device to an input terminal of the second signalling device; transmitting a signal from the first signalling device to the second signalling device by (i) varying the impedance of said output terminal in dependence upon the signal to be transmitted; (ii) sensing, via the communication link and the input terminal, the variation of impedance of said output terminal; and (iii) outputting a signal which varies in dependence upon the sensed variation of impedance.

The present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 schematically shows a battery comprising a number of battery cells connected in series, a central battery monitoring system for monitoring the condition of the battery as a whole and individual cell monitoring devices for monitoring the cells of the battery;

Figure 2 is a plot showing the battery-cell voltage distribution;

Figure 3 is a schematic diagram showing more detail of the central battery monitoring system shown in Figure 1;

Figure 4 is a schematic diagram of one of the cell monitoring devices shown in Figure 1;

Figure 5 schematically illustrates the way in which signals are passed between adjacent cell signalling devices in a first embodiment of the invention;

Figure 6 schematically illustrates the form of a cell monitoring device according to a second embodiment and the way in which it is connected to neighbouring cell monitoring devices;

Figure 7 schematically illustrates an alternative way in which signals can be transmitted between adjacent cell signalling devices;

Figure 8 is a schematic diagram of a battery cell monitoring device for use in a battery monitoring system according to a second embodiment of the present invention;

Figure 9 schematically shows a battery comprising a number of battery cells connected in series, a central battery control system for controlling the battery as a whole and individual battery cell controllers for controlling the cells of the battery;

Figure 10 is a schematic diagram of one of the battery cell control devices shown in Figure 9;

Figure 11 is a schematic diagram of a battery cell monitoring and control device for use in a battery monitoring and control system embodying the present invention;

Figure 12 is a schematic representation of an industrial battery in which the cells of the battery are connected in a series-parallel configuration; and

Figure 13 is a schematic diagram of a system for monitoring a plurality of industrial batteries.

A first embodiment of the present invention will now be described with reference to Figures 1 to 5. Figure 1 schematically shows an industrial battery, generally indicated by reference numeral 1, comprising a number of lead acid battery cells C_1, C_2, C_3 ... C_n connected so that the negative terminal C_i^- of cell C_i is connected to the positive terminal C_{i-1}^+ of preceding cell C_{i-1} and the positive terminal C_i^+ of cell C_i is connected to the negative terminal C_{i+1}^- of the succeeding cell C_{i+1}, whereby the negative terminal C_1^- of the first cell C_1 is the negative terminal of the battery and the positive terminal C_n^+ of the last cell C_n is the positive terminal of the battery. Since the battery cells are lead acid, they each provide approximately 2 volts and the voltage of the battery as a whole will be approximately 2n volts. Figure 2 shows the voltage characteristic of the industrial battery showing each cell's terminal potential versus the cell's position in the series. As shown, this voltage characteristic has a staircase shape, with each stair having a height equal to the voltage V_{CELL} of the respective battery cell C_i. For industrial applications a voltage of 120 volts is often required. Therefore, 60 series connected lead acid or 100 series connected Nicad battery cells would be required. Sometimes, each cell in the series connection is connected in parallel with one or more similar cells, so as to provide redundancy, so that the battery will not fail if a single cell fails.

Figure 1 also shows a central battery monitoring system 3 which is powered by the battery 1 via connectors 4 and 6, which connect the central battery monitoring system 3 to the negative terminal C_1^- and the positive terminal

C_n^+ of the battery 1, respectively. The battery monitoring system 3 monitors the status of the industrial battery 1 as a whole, based on charging and discharging characteristics of the battery (determined by monitoring the battery voltage from connectors 4 and 6 and the current being drawn from or supplied to the battery 1, which is sensed by current sensor 8, whilst the battery is being charged and subsequently discharged), the ambient temperature (input from temperature sensor 5) and on information relating to the efficiency characteristics of the battery cells (provided by the battery cell manufacturer). The monitoring results can be stored in the central battery monitoring system 3 or they can be transmitted to a remote user (not shown) via the telephone line 7.

Each of the battery cells C_i, shown in Figure 1, also has a battery cell monitoring device CM_i mounted on top of the cell between its positive and negative terminals C_i^+ and C_i^- respectively, which monitors the status of the cell C_i. Each cell monitoring device CM_i is powered by the cell C_i which it monitors and communicates with the central battery monitoring system 3 via a two-wire communication link 9. The communication link 9 links the cell monitoring devices CM_i in series in a daisy chain configuration to the central battery monitoring system 3, so that communications from the central battery monitoring system 3 to the cell monitoring devices CM_i pass on one wire from left to right along the communication link 9 and communications from the cell monitoring devices CM_i to the central battery monitoring system 3 pass on the other wire from right to left along the communication link 9. Each cell monitoring device CM_i has its own cell identification or address, which, in this embodiment, is set in advance using DIP-switches

mounted in the device. This allows communications from the central battery monitoring system 3 to be directed to a specific cell monitoring device and allows the central battery monitoring system 3 to be able to identify the source of received communications.

The battery monitoring system shown in Figure 1 operates in two modes. In the first mode, the central battery monitoring system 3 monitors the condition of the industrial battery 1 as a whole and polls each of the cell monitoring devices CM_i in turn. During this mode, each of the cell monitoring devices CM_i listens to communications from the central battery monitoring system 3 on the communication link 9 and responds when it identifies a communication directed to it. When polled, each cell monitoring device CM_i performs a number of tests on the corresponding battery cell C_i and returns the results of the tests back to the central battery monitoring system 3 via the communication link 9.

In the second mode of operation, the central battery monitoring system 3 listens for communications on the communication link 9 from the cell monitoring devices CM_i indicating that there is a faulty condition with one of the battery cells C_i. In this second mode of operation, each cell monitoring device CM_i continuously monitors the corresponding battery cell C_i and, upon detection of a faulty condition, checks that the communication link 9 is free and then sends an appropriate message back to the central battery monitoring system 3 via the communication link 9.

Figure 3 is a schematic diagram of the central battery monitoring system 3 shown in Figure 1. As shown, the central battery monitoring system 3 comprises a CPU 11

for controlling the operation of the central battery monitoring system 3. The CPU 11 is connected, via data bus 12, to a main memory 13 where data from the input sensors is stored and where test programs are executed, to a display 15 which displays the battery's current status and to a mass storage unit 17 for storing the sensor data and the results of the battery tests. The mass storage unit 17 can be fixed within the central battery monitoring system 3, but is preferably a floppy disk or a PCMIA memory card which can be withdrawn and input into an operator's personal computer for analysis. An operator can also retrieve the stored data and results and control the set up and initialisation of the central battery monitoring system 3 via the RS-232 serial interface 18. As mentioned above, instead of storing the test results in the mass storage unit 17, they can be transmitted via a modem 21 and telephone line 7 to a remote computer system (not shown) for display and/or analysis. In this embodiment, if there is a fault with one of the battery cells C_i or if there is some other faulty condition, the CPU 11 triggers a local alarm 23 to alert a technician that there is a fault with the battery 1 or with one or more of the battery cells C_i. In this embodiment, the conditions which define a fault and their thresholds are user definable and set in advance.

The central battery monitoring system measures the total battery capacity in Amp-hours (Ahr) or Watt-hours (Whr), the actual or remaining battery capacity as a percentage of the total battery capacity and the internal resistance of the battery 1 as a whole. The cental battery monitoring system 3 can also measure the internal resistance of the individual cells from the data received from the individual cell monitoring devices CM_i received via the communication link 9 and the communication

circuit 19. Although the central battery monitoring system 3 continuously monitors the battery 1, the sensor data and the other battery data, i.e. the remaining battery capacity etc, are only stored periodically in the mass storage unit 17 in order to save storage space. The period is specified in advance by the user and in this embodiment is set at ten seconds. Furthermore, when the samples are stored, they are time and date stamped so that the battery charging and discharging behaviour can be monitored and used to detect the cause of an eventual battery failure. In this embodiment, the data which is to be stored is also filtered in order to try to identify and highlight important events, and the filtered data is also stored in the mass storage unit 17. What counts as an important event is user definable, but can be, for instance, a temperature increase of 2°C or a change in remaining battery capacity of greater than 1% of the total battery capacity.

As mentioned above, the status data of the battery, i.e. the battery voltage, the discharge/charge current, the battery temperature and the remaining and total battery capacities, are displayed on display 15. For simplicity, since the display 15 does not need to be continuously updated, it is only updated using the samples of the status data which are to be stored in mass storage unit 17. Therefore, in this embodiment, the display 15 is updated every ten seconds.

In this embodiment, the central battery monitoring system 3 is also used to control the battery charger (not shown) which is used to charge the battery 1. In particular, the central battery monitoring system 3 monitors the charging current, the remaining battery capacity, the ambient temperature etc and controls the operation of the

charger (not shown) so that the battery charging is in accordance with the specific charging procedures recommended by the battery manufacturer for the battery 1.

Since the total battery capacity also decreases with time (due to ageing), the central battery monitoring system 3 is programmed to perform regular (for example daily or monthly) automated measurements of the total battery capacity and the battery internal resistance. This allows the central battery monitoring system 3 to be able to build up a picture of the battery life characteristics and to be able to predict the battery end of life and the early detection of faulty conditions.

Figure 4 is a schematic diagram showing, in more detail, one of the cell monitoring devices CM_i shown in Figure 1. As shown, cell monitoring device CM_i comprises a microcontroller 31 for controlling the operation of the cell monitoring device CM_i and for analysing sensor data received from voltage interconnection sensor 33, cell voltage sensor 35, temperature sensor 37 and electrolyte level/PH sensor 39.

The voltage interconnection sensor 33 measures the voltage drop between the cell being monitored and its neighbouring cells, by measuring the potential difference between each terminal of the cell C_i and the respective terminal connections which connects cell C_i with its neighbouring cells. Ideally, there should be no voltage drop between each terminal and the corresponding terminal connection. However, due to chemical deposits accumulating at the cell terminals with time, or because of cell malfunction, a difference in potential between the cell terminals and the corresponding connectors

sometimes exists, indicating that there is a fault, either with the battery cell C_i or with the interconnection with a neighbouring cell. The cell voltage sensor 35 is provided for sensing the potential difference between the positive terminal C_i^+ and the negative terminal C_i^- of the cell C_i which it is monitoring. The temperature sensor 37 senses the cell temperature locally at the cell C_i. By monitoring the local temperature at each cell C_i, it is possible to identify quickly faulty cells or cells which are not operating efficiently. The electrolyte level/PH sensor senses the electrolyte level and/or the electrolyte PH of the battery cell C_i which it is monitoring.

The microcontroller 31 analyses the data input from the sensors and monitors for faulty conditions and reports to the central battery monitoring system 3 via the communication link 9. Since the microcontroller 31 processes digital data, and since the signals received from the sensors and the messages received from the battery monitoring system 3 are analogue signals, the microcontroller 31 has a built-in analogue to digital convertor (not shown) so that it can convert the sensor data and the received messages into corresponding digital signals. In order to power the cell monitoring device CM_i, the positive terminal C_i^+ and the negative terminal C_i^- of cell C_i are connected to the input of a DC to DC convertor 57, which generates, relative to the ground of cell C_i (which equals the voltage potential of the negative terminal C_i^- of cell C_i) the voltage V_{cc}^i, which is used to power the microcontroller 31 and the other components in the device and which in this embodiment is C_i^- + 3 Volts.

Since the cell monitoring devices are connected in series

by the communication link 9, each cell monitoring device CM_i is operable (i) to receive up-link communications originating from the central battery monitoring system 3 on wire 9a of the communication link 9 for reception by itself and/or for onward transmission to the next cell monitoring device CM_{i+1}; (ii) to receive down-link communications from cell monitoring device CM_{i+1} on wire 9b of the communication link 9 for transmission back to the central battery monitoring system 3; and (iii) to transmit down-link communications generated by itself back to the central battery monitoring system 3 on wire 9b of the communication link 9.

As shown in Figure 4, in this embodiment, the microcontroller 31 receives up-link communications originating from the central battery monitoring system 3 via wire 9a, potential divider 41 and comparator 43. The microcontroller 31 identifies whether or not the received message from the central battery monitoring system is for it or if it is for onward transmission to the next cell monitoring device CM_{i+1}. If the message is for the current cell monitoring device CM_i, then the microcontroller 31 decodes the message and takes the appropriate action. If the received message is for onward transmission, then the microcontroller 31 regenerates the message and outputs it to wire 9a via output block 45. In this embodiment, the messages transmitted are square-wave signals representing digital data. The signals are encoded for error correction purposes and the microcontroller 31 checks for errors in the received messages. Since the microcontroller 31 regenerates the messages for transmission to the next cell monitoring device CM_{i+1}, the timing between the transitions in the signal levels can be resynchronised, thereby reducing any errors caused by the transmission

of the pulses along the communication link 9.

In a similar manner, down-link messages received from cell monitoring device CM_{i+1} on wire 9b are passed via potential divider 47 and comparator 49 to the microcontroller 31. In this embodiment, all down-link communications are for transmission back to the central battery monitoring system 3. Therefore, the micro-controller 31 checks for any errors in the received data and, if possible, corrects them. The microprocessor 31 then regenerates the message and outputs it to wire 9b via output block 51 for onward transmission back to the central battery monitoring system 3.

The way in which the messages are transmitted between the cell monitoring devices will now be described in more detail with reference to Figure 5. Up-link messages originating from the central battery monitoring system 3 which are re-transmitted by the microcontroller 31 of cell monitoring device CM_{i-1} are applied on line 32 to the gate electrode of the MOSFET Q_1^{i-1}. The source electrode of the MOSFET Q_1^{i-1} is connected to the ground C_{i-1}^- of cell monitoring device CM_{i-1} and the drain electrode is connected, via resistors R_a^i, R_b^i and R_c^{i-1}, to V_{cc}^i output by the DC/DC converter 57 in cell monitoring device CM_i. In operation, when the microcontroller 31 in the cell monitoring device CM_{i-1} outputs a voltage low (representing a binary 0) on line 32, the MOSFET Q_1^{i-1} does not allow current to flow from the drain electrode to the source electrode and therefore effectively open circuits the connection between V_{cc}^i and C_{i-1}^-. Therefore, when a voltage low is applied to the gate electrode of MOSFET Q_1^{i-1}, a voltage of approximately V_{cc}^i is applied on line 34 to the comparator 43, where it is compared with reference voltage V_{ref1}^i. When the microprocessor 31 of

cell monitoring device CM_{i-1} outputs a voltage high (representing a binary 1) on line 32, the MOSFET Q_1^{i-1} is switched on and current can flow from the drain electrode to the source electrode. Therefore, current will flow from V_{cc}^i through resistors R_a^i, R_b^i and R_c^{i-1} through the MOSFET Q_1^{i-1} to the ground C_{i-1}^- of cell monitoring device CM_{i-1}. As a result, V_{cc}^i - X volts will be applied on line 34 to the comparator 43, where it is compared with the reference voltage V_{ref1}^i. The value of X depends upon the difference between V_{cc}^i and C_{i-1}^- and the values of the resistors R_a^i, R_b^i and R_c^{i-1}. Provided the value of the reference voltage V_{ref1}^i is between the voltage levels applied to the comparator 43 on line 34 when the MOSFET Q_1^{i-1} is switched on and when it is switched off, the output of the comparator 43 will be a square-wave signal 36 varying between the ground potential C_i^- and V_{cc}^i of cell monitoring device CM_i in synchronism with the variation of the square-wave signal 38 applied to the gate electrode of MOSFET Q_1^{i-1} of cell monitoring device CM_{i-1}. Therefore, messages encoded within the variation of the signal applied to the MOSFET Q_1^{i-1} in cell monitoring device CM_{i-1} are transferred from cell monitoring device CM_{i-1} to cell monitoring device CM_i.

In a similar manner, down-link messages output by the microcontroller 31 in cell monitoring device CM_i for transmission back to the central battery monitoring system 3 are applied to the gate electrode of MOSFET Q_2^i on line 40. The drain electrode of MOSFET Q_2^i is raised to the potential V_{cc}^i and the source is connected, via resistors R_d^i, R_e^{i-1} and R_f^{i-1}, to the ground potential C_{i-1}^- of cell monitoring device CM_{i-1}. In operation, when the microcontroller 31 in the cell monitoring device CM_i outputs a voltage low on line 40, the MOSFET Q_2^i does not allow current to flow from the drain electrode to the

source electrode and therefore effectively open circuits the connection between V_{cc}^{i} and C_{i-1}^{-}. Therefore, when a voltage low is applied to the gate electrode of MOSFET Q_2^{i}, approximately zero volts is applied on line 42 to the comparator 49, where it is compared with reference voltage V_{ref2}^{i-1}. When the microcontroller 31 of cell monitoring device CM_i outputs a voltage high on line 40, the MOSFET Q_2^{i} is switched on and current flows from V_{cc}^{i} through resistors R_d^{i}, R_e^{i-1} and R_f^{i-1} to the ground C_{i-1}^{-} of the cell monitoring device CM_{i-1}. As a result, V_{cc}^{i} - Y volts will be applied on line 42 to the comparator 49, where it is compared with the reference voltage V_{ref2}^{i-1}. The value of Y depends upon the difference between V_{cc}^{i} and C_{i-1}^{-} and the values of resistors R_d^{i}, R_e^{i-1} and R_f^{i-1}. Again, provided the value of the reference voltage V_{ref2}^{i-1} is between the voltage levels applied to the comparator 49 on line 42 when the MOSFET Q_2^{i} is switched on and when it is switched off, the output of the comparator 49 will be a square-wave signal 44 varying between the ground potential C_{i-1}^{-} and V_{cc}^{i-1} of cell monitoring device CM_{i-1} in sychronism with the variation of the signal 46 applied to the gate electrode of MOSFET Q_2^{i} of cell monitoring device CM_i. Therefore, messages encoded within the variation of the signal applied to MOSFET Q_2^{i} are transferred from cell monitoring device CM_i to cell monitoring device CM_{i-1}.

The values of the resistors R_a^{i} to R_f^{i} in each cell monitoring device CM_i are chosen in order (i) to buffer the input and output terminals of the cell monitoring devices CM_i; (ii) to reduce power consumption of the cell monitoring devices CM_i; and (iii) to provide the necessary voltage division with respect to the difference in voltage between adjacent cell monitoring devices.

As those skilled in the art will appreciate, the above technique for transferring up-link and down-link data between cell monitoring devices CM_{i-1} and CM_i will only work provided the difference between V_{cc}^i and C_{i-1}^- does not exceed the operating range of the MOSFET switches Q_1^{i-1} and Q_2^i. In this embodiment, each battery cell C_i is provided with a cell monitoring device CM_i, the difference in operating potentials of adjacent cell monitoring devices is approximately two volts and V_{cc}^i is three volts more than the ground potential of the cell monitoring device. Therefore, in this embodiment, the difference between V_{cc}^i and C_{i-1}^- is approximately five volts. MOSFET transistors Q which can operate with such a loading are readily available. Indeed, there are some commercially available MOSFETs which can operate with a loading of up to sixty volts. Therefore, this technique of transmitting data between adjacent cell monitoring devices can be used in most practical situations, even in an embodiment where, for example, one cell monitoring device is provided for every tenth battery cell C_i.

Each of the cell monitoring devices CM_i operate in a similar manner. However, it should be noted, that in this embodiment, the first cell monitoring device CM_1 has the same ground or reference voltage as the central battery monitoring system 3. Therefore, in this embodiment, it is not necessary to use the potential divider 41 and the comparator 43 of the up-link nor the output block 51 in the down-link of the first cell monitoring device CM_1, although these are usually provided in order to standardise each of the cell monitoring devices CM_i. Similarly, the last cell monitoring device CM_n will not transmit data to nor receive data from a subsequent cell monitoring device. Therefore, cell monitoring device CM_n does not need the

output block 45 in the up-link nor the potential divider 47 and the comparator 49 in the down-link. However, these are usually provided so that all the cell monitoring devices CM_i are the same.

The battery monitoring system described above has the following advantages:

(1) There is no need for voltage isolation between the cell monitoring devices CM_i or between the first cell monitoring device CM_1 and the central battery monitoring system 3. Therefore, each cell monitoring device CM_i will only consume a few milli-amps and only requires very inexpensive and readily available DC to DC converters for converting the battery cell voltage to the supply voltage needed by the microcontroller 31.

(2) Since electrical isolation is not required between the cell monitoring devices CM_i, there is no longer a need for relatively expensive voltage isolated links between the cell monitoring devices. In the embodiment described, each cell monitoring device CM_i is linked to its neighbours by two wires. The cost of the battery monitoring system is therefore low and system installation is simplified.

(3) Continuous monitoring of all the cells C_i in battery 1 becomes economical and practical, and the user can be informed in real-time if one or more of the battery cells C_i is under-performing or is faulty.

(4) The internal resistance of each cell C_i can be determined in real-time and without having to disconnect the cell from the battery, since the central battery monitoring system 3 is capable of measuring battery

charging and discharging current (which is the same as the cell current) and can correlate it with individual cell voltages (determined by the cell monitoring devices) in order to calculate each cell's internal resistance.

(5) Each cell monitoring device CM_i is able to measure the voltage drop on cell to cell interconnections and indicate a faulty interconnection condition, usually due to chemical deposits accumulating at the cell terminals with time or because of cell malfunction.

(6) Since each cell monitoring device CM_i is able to measure the cell voltage and the cell temperature, it is possible to increase the probability of detecting a faulty cell. Therefore, the industrial battery need only be serviced when required.

(7) Since each cell monitoring device CM_i can read the corresponding cell voltage, cell temperature etc at the same time as the other cell monitoring devices, the data produced by each cell monitoring device is less likely to be corrupted by changes in load and/or changes in ambient temperature which occur with time, as compared with prior art systems which take readings from the individual cells one at a time.

A number of alternative embodiments will now be described, which operate in a similar manner to the first embodiment. Accordingly, the description of these alternative embodiments will be restricted to features which are different to those of the first embodiment.

Figure 6 illustrates an embodiment in which messages can be transmitted uplink as well as downlink between adjacent cell monitoring devices CM_i, via a single

communication wire 9 which connects the cell monitoring devices in series. As shown in Figure 6, each cell monitoring device CM_i has the same potential dividers 41 and 49, comparators 43 and 47, and output blocks 45 and 51 as in the first embodiment. The difference between this embodiment and the first embodiment is that the uplink and the downlink between adjacent cell monitoring devices share a common communication wire 9. This is achieved by connecting, at connection 62, the output of block 51 in cell monitoring device CM_i to the connection between potential divider 41 in cell monitoring device CM_i and the output block 45 in cell monitoring device CM_{i-1} and by connecting, at connection 64, the potential divider 49 in cell monitoring device CM_{i-1} to the connection between potential divider 41 in cell monitoring device CM_i and the output block 45 in cell monitoring device CM_{i-1}.

Since both the uplink and the downlink connection between adjacent cell monitoring devices is via the same wire 9, communications between cell monitoring devices can be in one direction only at any given time. To achieve this, during a downlink communication, MOSFET Q_1^{i-1} is switched off so that messages transmitted by switching the state of MOSFET Q_2^i pass via the potential divider 49 and the comparator 47 into the microcontroller (not shown) in cell monitoring device CM_{i-1}. Similarly, for uplink communications from, for example, cell monitoring device CM_i to cell monitoring device CM_{i+1}, the MOSFET Q_2^{i+1} is switched off so that the output block 51 has a high impedance and does not affect the operation of the potential divider 41. Further, as those skilled in the art will appreciate, in order for the potential dividers and output blocks to operate in the same way as in the first embodiment, the resistances of resistors R_a, R_b, R_e

and R_f must be relatively large compared to the resistances of resistors R_c and R_d. In this embodiment, with 2 volt battery cell voltages, $R_a = R_b = R_e = R_f = 10K$ ohms, $R_d = R_c = 2K$ ohms, $V_{ref1}^i = V_{ref2}^i = V_{cc}^i/2$ and $V_{cc}^i = C_i^- + 5V$. As those skilled in the art will appreciate, the cell monitoring device of this embodiment can easily be adapted to operate with any battery cell voltage, the only changes that are required are the resistor values, the reference voltage values and the maximum allowable drain to source voltage of the MOSFETs.

As those skilled in the art will appreciate, in the above embodiments, data was transmitted between adjacent cell monitoring devices by varying the output impedance of an output block in the cell monitoring device which is to transmit the message and by detecting this variation in the cell monitoring device which is to receive the message. For example, when up-link message data is to be transmitted from cell monitoring device CM_{i-1} to cell monitoring device CM_i, the impedance of output block 45 in cell monitoring device CM_{i-1} is varied in dependence upon the data to be transmitted - when a voltage low is to be transmitted, the impedance of output block 45 is made to be very high, whereas when a voltage high is to be transmitted, the impedance of output block 45 is made to be relatively low. This variation of the impedance of output block 45 is detected by the potential divider 41 and the comparator 43 in the cell monitoring device CM_i which is to receive the transmitted up-link message. As those skilled in the art will appreciate, there are various ways of varying an output impedance of a cell monitoring device in dependence upon the data to be transmitted and various ways of detecting that variation in the adjacent cell monitoring device. Figure 7 shows one of these alternative embodiments.

In the embodiment shown in Figure 7, the output impedance of cell monitoring device CM_{i-1} is varied in the same way as it was varied in the first embodiment but this variation is detected in cell monitoring device CM_i in a different manner. In particular, in this embodiment, a current detector 48 is used to detect the changes in current flowing between the V_{cc}^{i} terminal in cell monitoring device CM_i to the ground potential C_{i-1}^{-} in cell monitoring device CM_{i-1}. In operation, when a voltage low is applied to the gate electrode of MOSFET Q_1^{i-1}, the MOSFET is open and no current flows down line 50. However, when a voltage high is applied to the gate electrode of MOSFET Q_1^{i-1}, the MOSFET opens and current is drawn down line 50. This change in current is detected by the current sensor 48. More specifically, each time there is a transition from a voltage high to a voltage low (or vice versa) applied to the gate electrode of MOSFET Q_1^{i-1}, a voltage spike is induced in the current detector 48. As illustrated in Figure 7, in response to up-link message data 52 being applied to the MOSFET Q_1^{i-1}, a train of voltage spikes 53 are induced in the current detector 48 and passed to a spike detector 54 which regenerates and outputs the up-link message data 52 for transmission to the microcontroller (not shown). The resistors R_1 and R_2 are provided in order to reduce the power consumed by each of the cell monitoring devices CM_i and in order to buffer the input and output of the respective cell monitoring devices.

In the above embodiments, a MOSFET was used as a device whose impedance can be varied in dependence upon the message data to be transmitted. As those skilled in the art will appreciate, these MOSFETs can be replaced by any electronic switches (solid-state relays, electro-mechanical relays, J-FETs, transistors etc) and, in

embodiments where the up-link and the down-link messages are received and re-transmitted by a microcontroller, can be omitted altogether. This is because the output impedance of the output pin of the microcontroller varies in dependence upon whether it is outputting a voltage high or a voltage low. Therefore, for example, the output pin from the microcontroller in cell monitoring device CM_{i-1} could be directly connected to the potential divider 41 in cell monitoring device CM_i. However, such an embodiment is not preferred, because the microcontroller can be damaged by the voltage applied to the output pin from the adjacent cell monitoring device.

In the above embodiments, each cell monitoring device CM_i has a microcontroller 31 for receiving messages from the central battery monitoring system 3, for analysing data from various sensors and for sending data back to the central battery monitoring system 3 via the communication link 9. Figure 8 schematically shows an alternative cell monitoring device CM_i of a second embodiment which does not use a microcontroller 31.

In particular, as shown in Figure 8, each cell monitoring device CM_i comprises a signal generator 71 which receives sensor signals from the cell voltage sensor 35 and the temperature sensor 37 and outputs, on line 73, a signal which varies in dependence upon the received sensor signals. The signal generator 71 may comprise a voltage controlled oscillator which outputs an alternating signal whose frequency varies in dependence upon an input voltage from, for example, the cell voltage sensor 35. The signal output from the signal generator 71 is applied to a variable impedance device 77 whose impedance is varied in dependence upon the signal output from the signal generator 71. The variation of the impedance of

the variable impedance device 77 is detected by the cell monitoring device CM_{i-1} to thereby regenerate the message transmitted by the signal generator 71. In order to be able to receive messages from cell monitoring device CM_{i+1} for onward transmission back to the central battery monitoring system 3, as shown in Figure 8, each cell monitoring device CM_i also comprises an impedance monitor 78 which detects the variation of the impedance of the variable impedance device 77 in the cell monitoring device CM_{i+1} from which it regenerates the message transmitted from cell monitoring device CM_{i+1}. This regenerated message is then applied via line 79 to the variable impedance device 77 for onward transmission to cell monitoring device CM_{i-1}. As in the first embodiment, each cell monitoring device CM_i is powered by the cell C_i which it is monitoring. This is illustrated in Figure 8 by the connections C_i^+ and C_i^- which are connected to input terminals 74 and 76 respectively.

In the above embodiments, the system described was a battery monitoring system. Figure 9 schematically shows a third embodiment which is a control system for controlling the cells of an industrial battery. As shown, the control system has a similar architecture to the battery monitoring system shown in Figure 1, except that the central battery monitoring system 3 is now a central battery control system 80 and the cell monitoring devices CM_i are now battery cell control devices CC_i. As in the monitoring system of Figure 1, the central battery control system 80 communicates with each of the cell controlling devices CC_i via the communication link 9.

Figure 10 schematically shows one of the battery cell control devices CC_i shown in Figure 9. Each cell controlling device CC_i is used to control the topping up

of acid and water in the respective battery cell C_i, in response to an appropriate control signal received from the central battery control system 80. As in the first embodiments, each cell control device CC_i is powered by the cell which it is to control, as represented by inputs C_i^+ and C_i^- applied to input power terminals 81 and 83 respectively. In this embodiment, each cell control device CC_i is arranged to receive messages from the central battery control system (not shown), but not to transmit messages back. Therefore only a single wire communication link 9 is required in this embodiment. In operation, the variation in the output impedance of cell control device CC_{i-1} is detected by the impedance monitor 78 from which the up-link message data is regenerated. In this embodiment, the micro-controller 91 is not connected on-line. In other words, the regenerated up-link message data is not decoded and then regenerated by the microcontroller 91 for onward transmission. Instead, the up-link message data regenerated by the impedance monitor 78 is directly used to vary the impedance of the variable impedance device 77 so that the up-link message data is transmitted onto the next cell control device CC_{i+1}. The microcontroller 91 monitors the received messages via connection 93 and outputs appropriate control signals to output terminals 95 and 97 when the received signals are directed to it. The control signals output to terminals 95 and 97 are used to control the position of valves 99 and 101 respectively, so as to control the amount of water and acid to be added to the battery cell C_i from the water tank 103 and the acid tank 105. The microcontroller 91 determines the amount of water and acid to add with reference to the sensor signals received from the electrolyte level/PH sensor 39. As those skilled in the art will appreciate, the advantage of not having the microcontroller 91 on-line

is that the messages are transmitted along the communications link 9 with minimum delay. However, the disadvantages are that the system becomes more prone to error caused by the desynchronisation of the voltage transitions as the messages are transferred from one cell control device to the next and that there is no error correction being performed on the message data transmitted between adjacent cell control devices.

In the above embodiments, a central battery monitoring system or a central battery control system was provided which monitored or controlled the system as a whole. Figure 11 schematically shows a cell monitoring and control device $CM\&C_i$ which can be used in a combined battery control and monitoring system in which there is no central battery monitoring and control system and in which each cell monitoring and control device $CM\&C_i$ communicates directly with the other cell monitoring and control devices. As in the other embodiments, each cell monitoring and control device $CM\&C_i$ is powered by the cell which it is monitoring and controlling, as represented by inputs C_i^+ and C_i^- applied to input power terminals 115 and 117 respectively. As shown in Figure 11, each cell monitoring and control device $CM\&C_i$ comprises a microcontroller 111 which receives sensor data from temperature sensor 37 and which outputs control data to output terminal 113 for controlling, for example, a liquid crystal display (not shown) mounted on the respective cell C_i.

In this embodiment, up-link data is regenerated by the impedance monitor 78a and then passed to the variable impedance device 77a for onward transmission to cell monitoring and control device $CM\&C_{i+1}$. Similarly, down-link message data is regenerated by the impedance monitor

78b and passed to the variable impedance device 77b for onward transmission to cell monitoring and control device $CM\&C_{i-1}$. As shown, in this embodiment, the micro-controller 111 is connected off-line to the up-link and the down-link by connections 123 and 125, so that each cell monitoring and control device $CM\&C_i$ can receive data from and transmit data to other cell monitoring and control devices.

Various modifications which can be made to the above described embodiments will now be described.

In the first embodiment, a cell monitoring device was used to monitor each cell of the battery. In a cheaper implementation, each cell monitoring device CM_i could be used to monitor two or more series connected battery cells C_i.

In the embodiments described, the cells are connected in series. It is possible to connect the battery cells C_i in a series-parallel or ladder configuration. Figure 12 shows such an interconnection of battery cells, in which cell C_{ia} is connected in parallel with cell C_{ib} and the parallel combinations C_{ia} and C_{ib} are connected in series for i = 1 to n. In the configuration shown in Figure 12, a single cell monitoring device CM_i is provided for monitoring each of the battery cells and the communication link 9 connects CM_{ia} to CM_{ib} and CM_{ib} to CM_{i+1a} etc. Alternatively, a single cell monitoring device could be used to monitor each parallel combination of battery cells C_{ia} and C_{ib}. Additionally, more than two battery cells can be connected in parallel.

In the above embodiments, the central battery monitoring and/or control system was provided at the zero volt

reference voltage end of the communication link 9. Alternatively, the central battery monitoring and/or control system could be connected at the high reference voltage end of the communication link 9. Alternatively still, the central battery monitoring and/or control system could be connected at both ends, thereby forming a circular communications path in which messages are transmitted to and received from the battery monitoring/controlling system in one direction through the cell monitoring/controlling devices. Therefore, each cell monitoring/controlling device only needs either an up-link or a down-link, depending on whether the messages are transmitted up or down the communication link 9.

In the above described embodiments, the communication link 9 comprised either one or two wires. As those skilled in the art will appreciate, the communication link 9 may comprise any number of wires along which data can be transmitted in parallel.

In the above embodiments, a separate central battery monitoring system or a central battery control system was provided. In an alternative embodiment, a combined battery monitoring and control system could be used to both monitor and control the battery.

In the above described embodiments, a single battery comprising a plurality of battery cells, is monitored and/or controlled by a central battery monitoring and/or controlling system. Figure 13 shows an alternative embodiment where a plurality of batteries B_i are provided, and wherein each battery B_i is monitored by its own central battery monitoring system BM_i which communicates with a remote operator's terminal 151 via a data bus 153. The data bus 153 may be a proprietary

data link or can be the public telephone exchange. In operation, each of the central battery monitoring systems BM_i monitors the respective battery B_i and reports its status back to the remote operator's terminal 151, where the condition of each of the batteries is monitored by a human operator. A similar system could also be provided for controlling or for monitoring and controlling a plurality of batteries.

In the above embodiments, the cell signalling devices are connected in series in a daisy chain configuration, with the position of each cell signalling device in the series communication link corresponding with the position of the cell or cells which are to power the cell signalling device in the series connection of battery cells. This is not essential. The cell signalling devices can be connected in any arbitrary series configuration relative to the series connection of battery cells. This is because the MOSFET switches Q_1 and Q_2 operate in the same manner irrespective of the voltage loading applied across its drain and source electrodes. However, in this case, the values of the resistors R_a to R_f in each cell monitoring/control device will be different and will be chosen so as to provide the necessary voltage division having regard to the difference in voltage between adjacent cell monitoring devices in the communications link.

The present invention is not limited by the exemplary embodiments described above, and various other modifications and embodiments will be apparent to those skilled in the art.

CLAIMS:

1. A signalling system for use with a plurality of series connected battery cells, comprising:

first and second cell signalling devices, each to be powered by a respective one or more of said plurality of battery cells; and

a communication link for connecting an output terminal of said first cell signalling device to an input terminal of said second cell signalling device;

characterised in that said first cell signalling device comprises means for varying the impedance of said output terminal in dependence upon a signal to be transmitted and in that said second cell signalling device comprises means for sensing, via said communication link and said input terminal, the variation of impedance of said output terminal and for outputting a signal which varies in dependence upon the sensed variation of impedance.

2. A signalling system according to claim 1, wherein said output terminal comprises a switch and wherein said first signalling device comprises means for opening and closing said switch in dependence upon the signal to be transmitted.

3. A signalling system according to claim 2, wherein said switch comprises a transistor.

4. A signalling system according to any preceding claim, wherein said second signalling device comprises a voltage source for connection to said input terminal and wherein said sensing means comprises a current sensor for sensing the variation of current drawn from said voltage source as a result of the variation of said

impedance of said output terminal.

5. A signalling system according to any of claims 1 to 3, wherein said second signalling device comprises a voltage source for connection to said input terminal and wherein said sensing means comprises a voltage divider for sensing the change in voltage across said voltage divider as a result of the variation of impedance of said output terminal.

6. A signalling system according to any preceding claim, wherein said second signalling device comprises an output terminal and means for varying the impedance of said output terminal in dependence upon a signal to be transmitted to another signalling device.

7. A signalling system according to claim 6, further comprising a plurality of said second signalling devices connected in series by said communication link.

8. A signalling system according to claim 7, wherein said signalling devices are arranged to transmit signals in one direction along said series connection communication link.

9. A signalling system according to claim 8, wherein said communication link comprises a single wire connecting the output terminal of one signalling device to the input terminal of an adjacent signalling device.

10. A signalling system according to claim 7, wherein said signalling devices are arranged so that signals can be transmitted in either direction between adjacent signalling devices.

11. A signalling system according to claim 10, wherein said communication link comprises two or more wires, at least one for transmitting signals in one direction and at least one for transmitting signals in the other direction between adjacent signalling devices.

12. A signalling system according to claim 10, wherein said communication link comprises a single wire, and wherein said signalling devices are arranged so that signals are transmitted between adjacent signalling devices in one direction only at any given time.

13. A signalling system according to any preceding claim, wherein each cell signalling device comprises at least one sensor input terminal operable to receive a signal from a sensor, which signal is indicative of a condition of the cell or cells which are to power the cell signalling device.

14. A signalling system according to any preceding claim, wherein each cell signalling device is operable to communicate, via said communication link, with a central battery monitoring system which is operable to monitor the battery cells as a whole.

15. A signalling system according to claim 14, wherein each cell signalling devices comprises:

at least one sensor input terminal operable to receive a signal from a sensor, which signal is indicative of a condition of the cell or cells which are to power the cell signalling device; and

a signal generator operable to generate the signal in dependence upon said sensor signal and to output said generated signal for transmission to said battery monitoring system.

16. A signalling system according to claim 15, wherein said central battery monitoring system is operable to poll each of said plurality of cell signalling devices in turn, and wherein upon being polled, each cell signalling device is operable to return a signal back to said central battery monitoring system via said communication link, which is indicative of said condition of the cell which is to power said cell signalling device.

17. A signalling system according to any of claims 14 to 16 when dependent upon claim 13, wherein said condition is the cell voltage and wherein said central battery monitoring system is operable to measure the battery charging and discharging current and to calculate the internal resistance of each battery cell by correlating said charging and discharging current with the cell voltages determined by the respective cell signalling devices.

18. A signalling system according to any preceding claim, wherein each cell signalling device is operable to receive a control signal from said communication link and comprises a signal generator operable to generate an actuation signal in dependence upon said received control signal and to output said generated actuation signal for controlling an actuator.

19. A signalling system according to claim 18, wherein each cell signalling device is operable to communicate, via said communication link, with a central battery control system which is operable to transmit said control signal to said communication link.

20. A signalling system according to claim 18 or 19,

wherein each cell signalling device comprises a sensor input terminal operable to receive a signal from an electrolyte level and/or electrolyte pH sensor, which signal is indicative of the electrolyte level and/or the electrolyte pH of the cell or cells which are to power the cell signalling device, and wherein upon receiving said control signal said cell signalling device is operable to output an actuation signal in dependence upon said sensor signal for controlling the addition of water and acid to the cell in order to control its electrolyte level and/or its electrolyte pH.

21. A signalling system according to any preceding claim, wherein each signalling device comprises a microcontroller which is operable to receive communications from and to transmit communications to said communication link.

22. A signalling system according to claim 21, wherein each microcontroller is arranged (i) to receive communications from said communication link; (ii) to determine if the received communication is for itself or for onward transmission; and (iii) if it is for onward transmission to resynchronise the received communication and to output the resynchronised communication for onward transmission.

23. A signalling system according to any preceding claim, wherein the signals to be transmitted comprise square-wave signals.

24. A signalling system according to any preceding claim, wherein each cell signalling device comprises a DC to DC converter which is operable to convert the cell voltage of the cell which is to power the cell signalling

device, to supply an operating voltage and a ground voltage for powering the components of the cell signalling device.

25. A signalling system according to any preceding claim, wherein said varying means is arranged to vary the resistance of the output terminal of said signalling device.

26. A signalling device for use in a signalling system according to any preceding claim, comprising:

an output terminal for connection to an adjacent cell signalling device via a communication link;

means for varying the impedance of said output terminal in dependence upon a signal to be transmitted to said adjacent signalling device;

an input terminal for receiving signals from another adjacent signalling device; and

means for sensing, via said communication link and said input terminal, the variation of impedance of an output terminal of said another adjacent signalling device and for outputting a signal which varies in dependence upon the sensed variation of impedance.

27. A cell signalling device for use in a signalling system according to any of claims 1 to 25, comprising:

a power input terminal connectable to the cell or cells which is or are to power said cell signalling device;

an output terminal for connection to an adjacent cell signalling device via said communication link;

means for varying the impedance of said output terminal in dependence upon a signal to be transmitted to said adjacent cell signalling device;

an input terminal for receiving signals from another

adjacent cell signalling device; and

means for sensing, via said communication link and said input terminal, the variation of impedance of an output terminal of said another adjacent cell signalling device and for outputting a signal which varies in dependence upon the sensed variation of impedance.

28. A cell signalling device having the cell signalling features of any of claims 1 to 25.

29. A signalling kit for use in a signalling system according to any of claims 1 to 25, comprising a plurality of cell signalling devices according to claim 26, 27 or 28.

30. A signalling kit according to claim 29, further comprising a communication link for connecting said plurality of cell signalling devices in series.

31. A signalling system according to any of claims 1 to 25 in combination with a plurality of series connected battery cells, wherein one or more of said battery cells are connected to a respective one of said cell signalling devices, for powering said cell signalling device.

32. A cell signalling device according to claim 27 or 28 in combination with a battery cell, wherein the terminals of said battery cell are connectable to said cell signalling device.

33. A signalling method for signalling between a plurality of series connected battery cells, the method comprising the steps of:

providing first and second cell signalling devices, each to be powered by a respective one or more of said

plurality of battery cells;

providing a communication link for connecting an output terminal of said first cell signalling device to an input terminal of said second cell signalling device;

transmitting a signal from said first cell signalling device to said second cell signalling device by:

i) varying the impedance of said output terminal in dependence upon the signal to be transmitted;

ii) sensing, via said communication link and said input terminal, the variation of impedance of said output terminal; and

iii) outputting a signal which varies in dependence upon the sensed variation of impedance.

34. A signalling system for use with a plurality of systems each operating at a different reference voltage, comprising:

first and second signalling devices, each to be powered by a respective one or more of said plurality of systems; and

a communication link for connecting an output terminal of said first signalling device to an input terminal of said second signalling device;

characterised in that said first signalling device comprises means for varying the impedance of said output terminal in dependence upon a signal to be transmitted and in that said second signalling device comprises means for sensing, via said communication link and said input terminal, the variation of impedance of said output terminal and for outputting a signal which varies in dependence upon the sensed variation of impedance.

ABSTRACT

A battery signalling system is provided which can be used to monitor and/or control a battery having a number of series connected battery cells. When used to monitor the battery cells, the battery signalling system can comprise a central battery monitoring system for monitoring the industrial battery as a whole, a number of cell monitoring devices for monitoring one or more battery cells and a communication link for connecting the cell monitoring devices in series in a daisy chain configuration to the central battery monitoring system. In operation, the central battery monitoring system can poll each of the cell monitoring devices in turn and can analyse the data received from a polled cell monitoring device to detect malfunctions and/or underperforming cells.

1/11

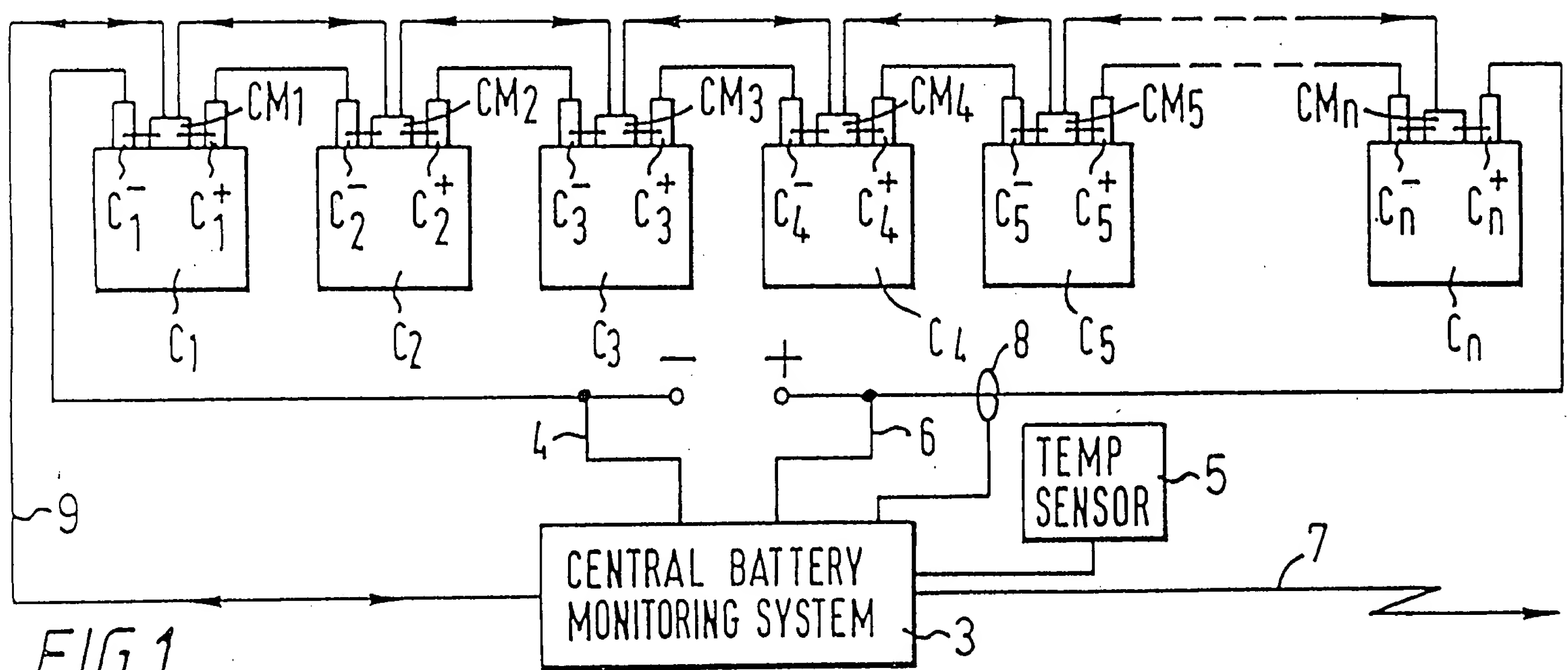


FIG.1

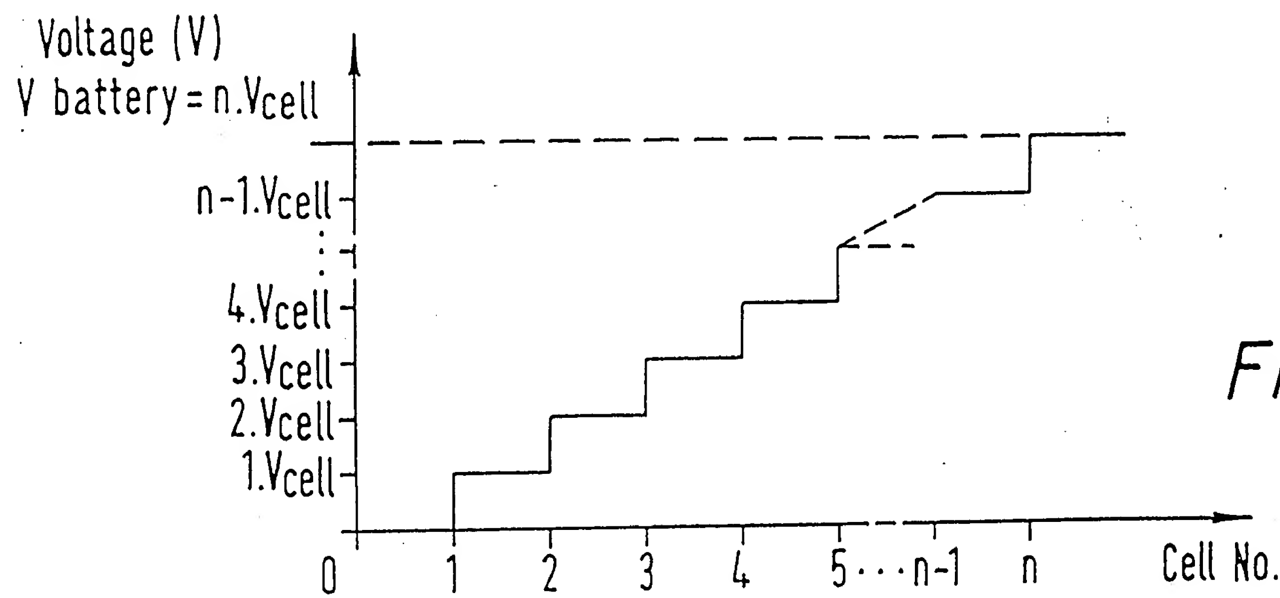


FIG.2

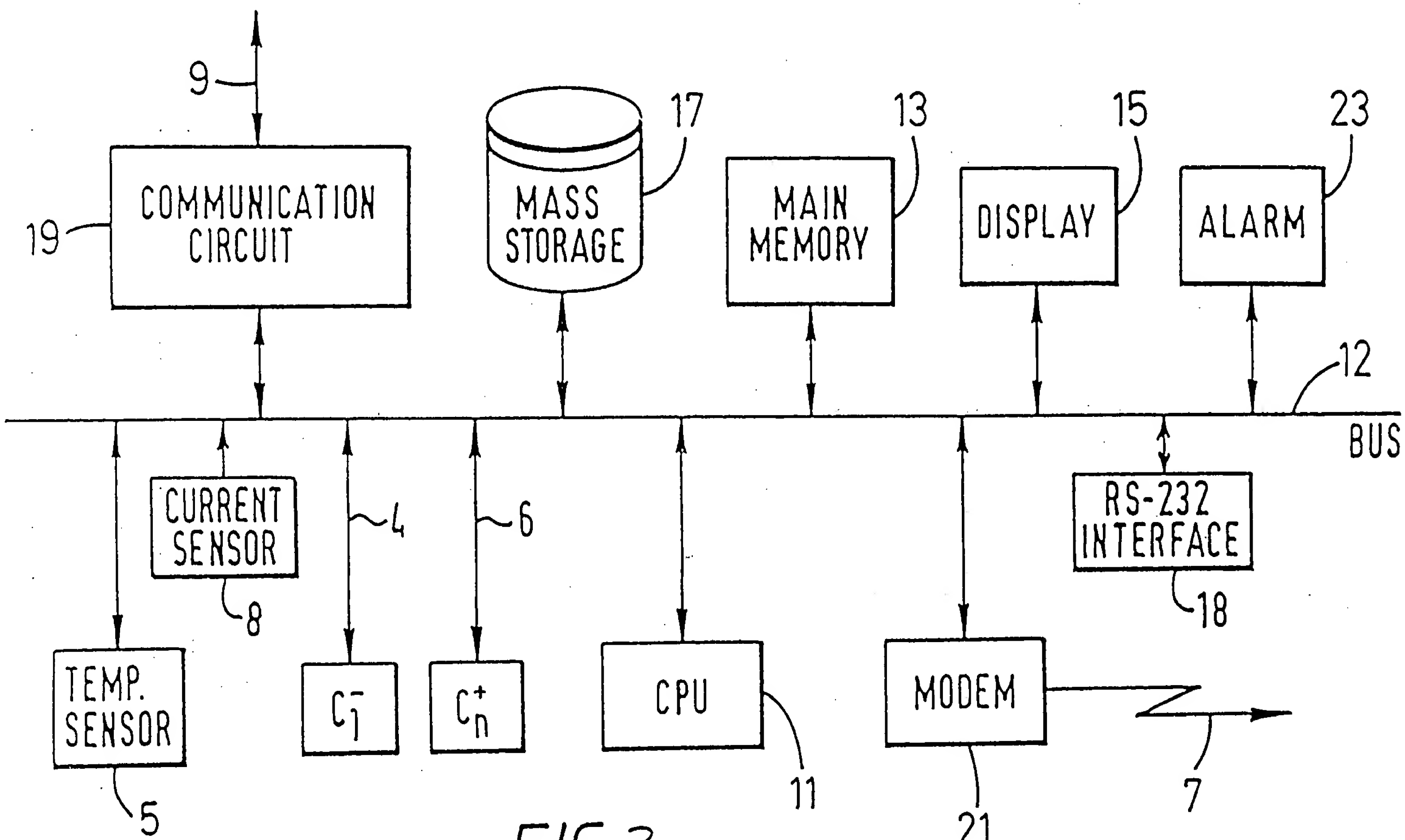
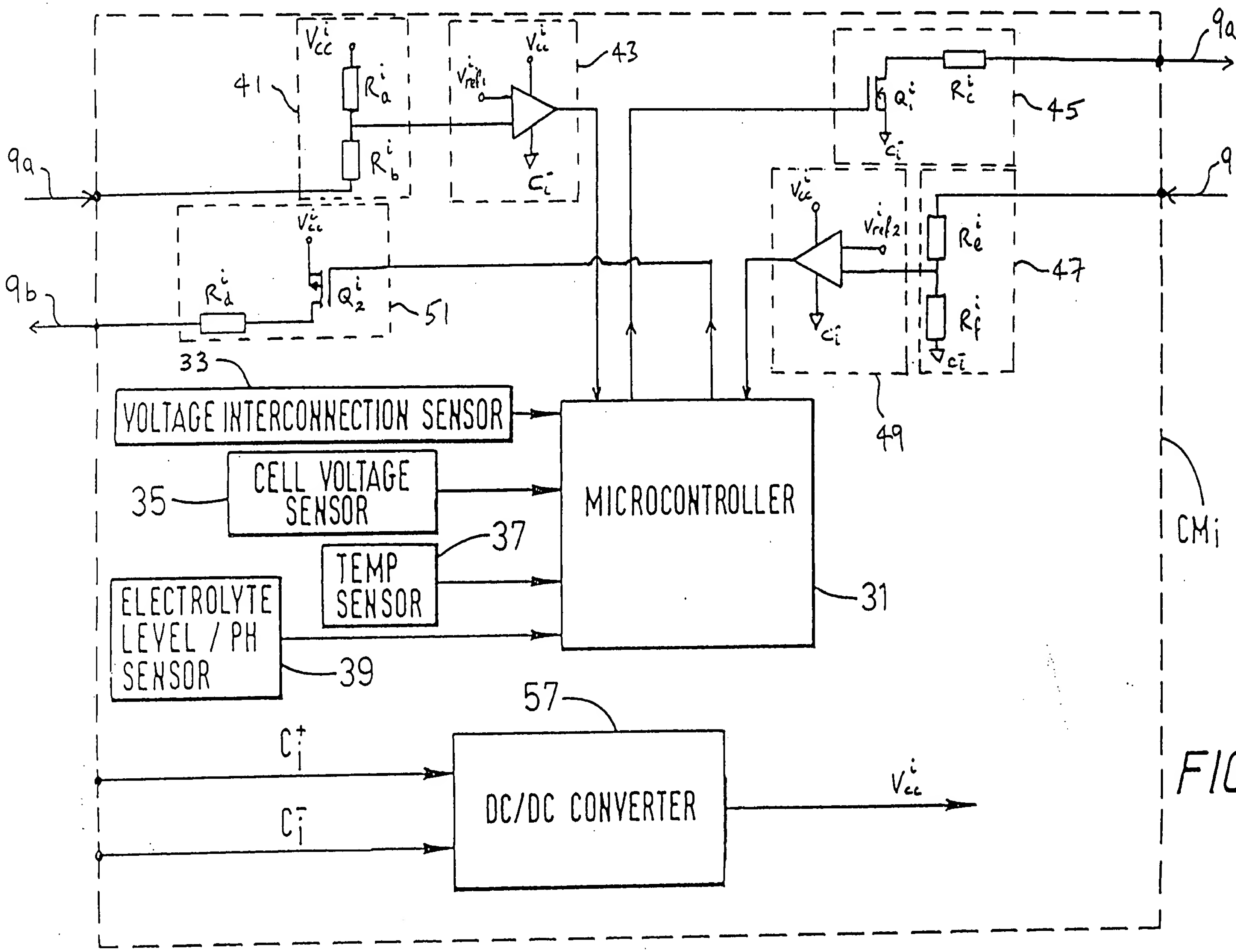

9
COMMUNICATION CIRCUIT
19
MASS STORAGE
17
MAIN MEMORY
13
DISPLAY
15
ALARM
23
12
BUS
CURRENT SENSOR
8
TEMP. SENSOR
5
4
6
CPU
11
MODEM
21
RS-232 INTERFACE
18
7

FIG. 3



VOLTAGE INTERCONNECTION SENSOR
CELL VOLTAGE SENSOR
TEMP SENSOR
ELECTROLYTE LEVEL / PH SENSOR
MICROCONTROLLER
DC/DC CONVERTER
CMi
9a
9b
41
43
45
47
49
51
33
35
37
39
31
57

FIG.4

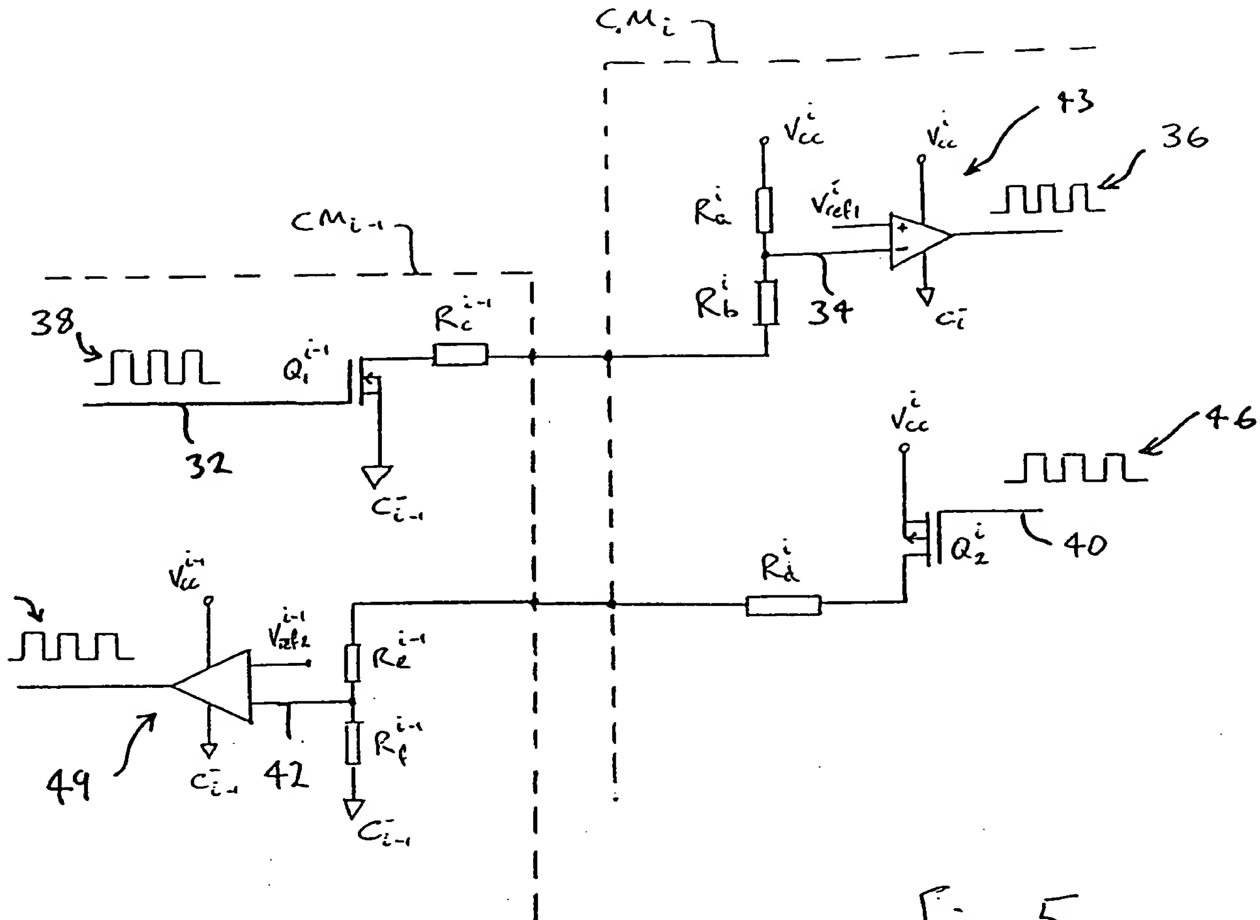

CMi
CMi-1
38
32
36
43
34
46
40
49
42

Fig 5

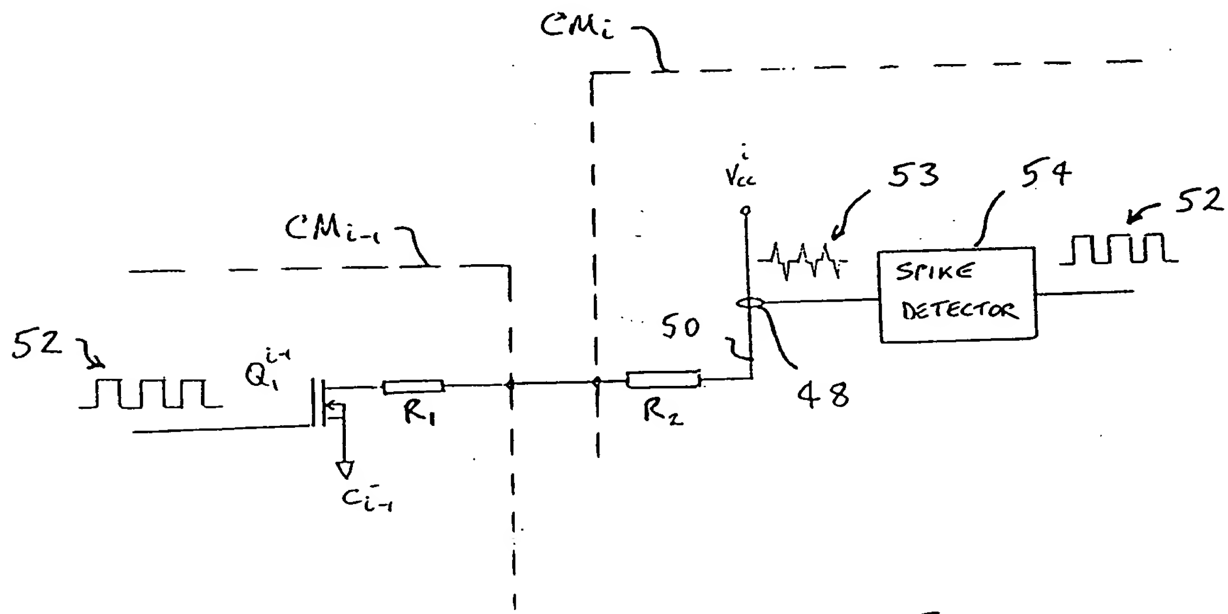

CMi
CMi-1
52
53
54
52
50
48
SPIKE DETECTOR

Fig 7

5/11

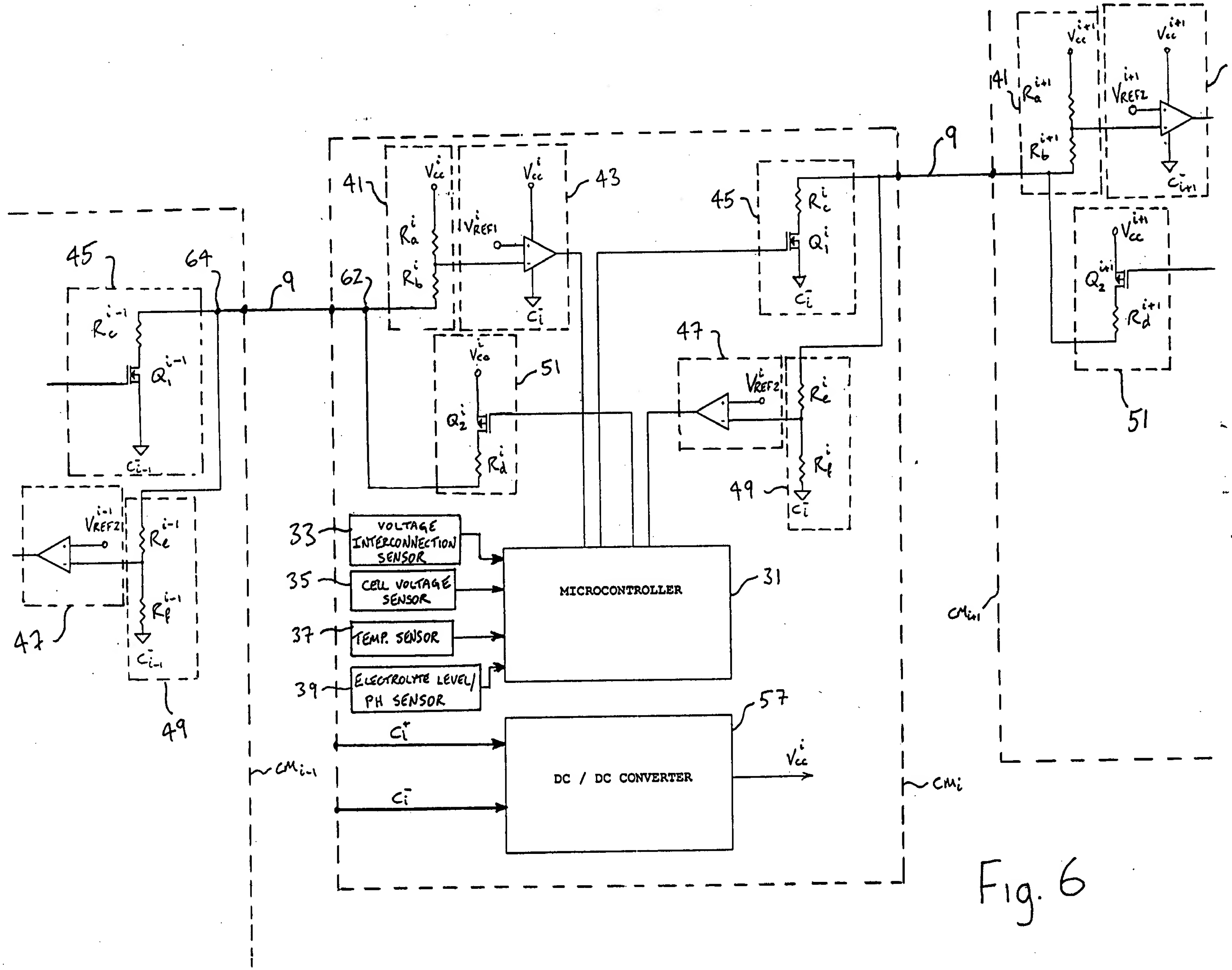
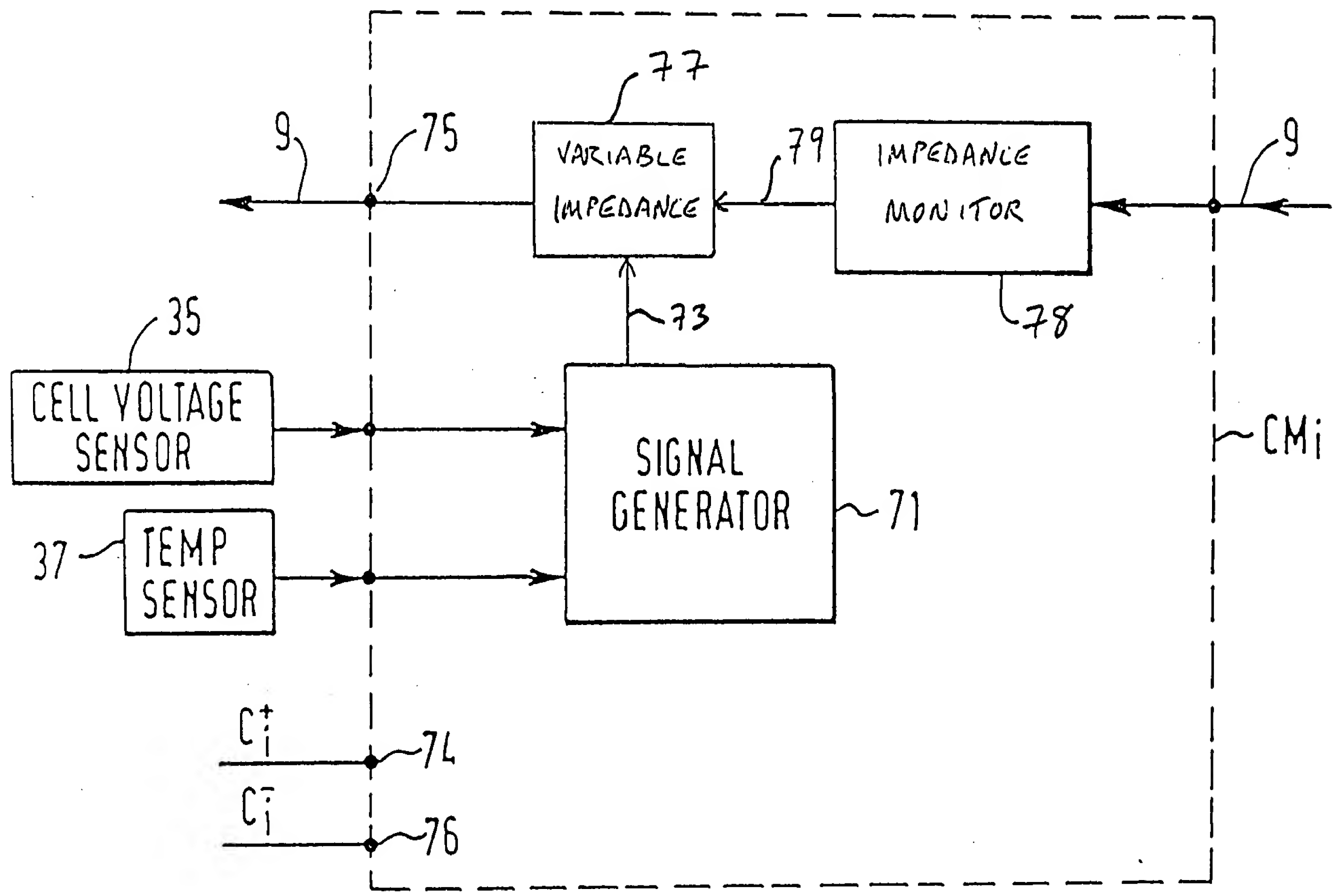

MICROCONTROLLER
DC / DC CONVERTER
VOLTAGE INTERCONNECTION SENSOR
CELL VOLTAGE SENSOR
TEMP. SENSOR
ELECTROLYTE LEVEL/ PH SENSOR
31
33
35
37
39
41
141
43
45
47
49
51
57
62
64
9
CM_{i-1}
CM_i
CM_{i+1}
V_{cc}^i
V_{REF1}^i
V_{REF2}^i
C_i^+
C_i^-

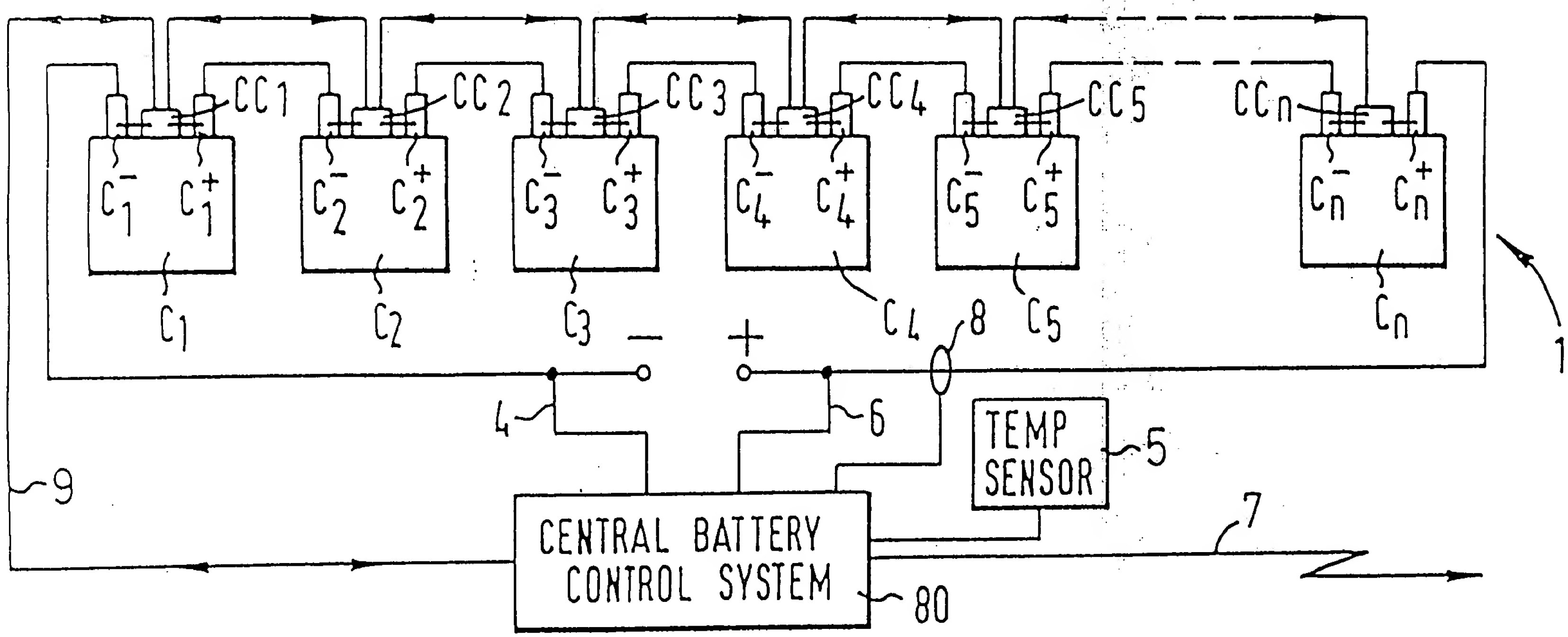
Fig. 6

FIG. 8

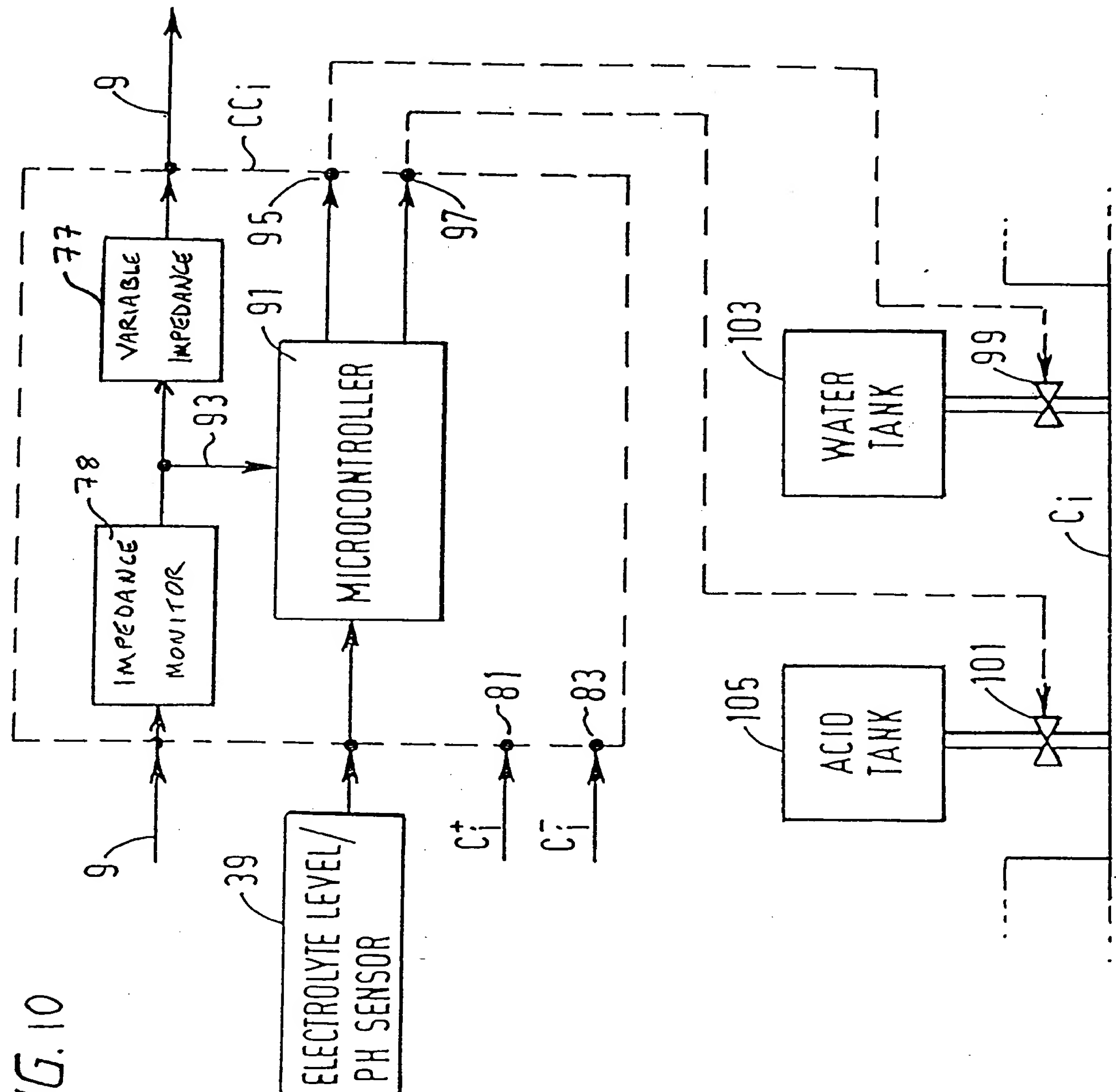


9
75
77
VARIABLE IMPEDANCE
79
IMPEDANCE MONITOR
9
78
73
35
CELL VOLTAGE SENSOR
SIGNAL GENERATOR
71
CMi
37
TEMP SENSOR
C+i
74
C-i
76

FIG. 9

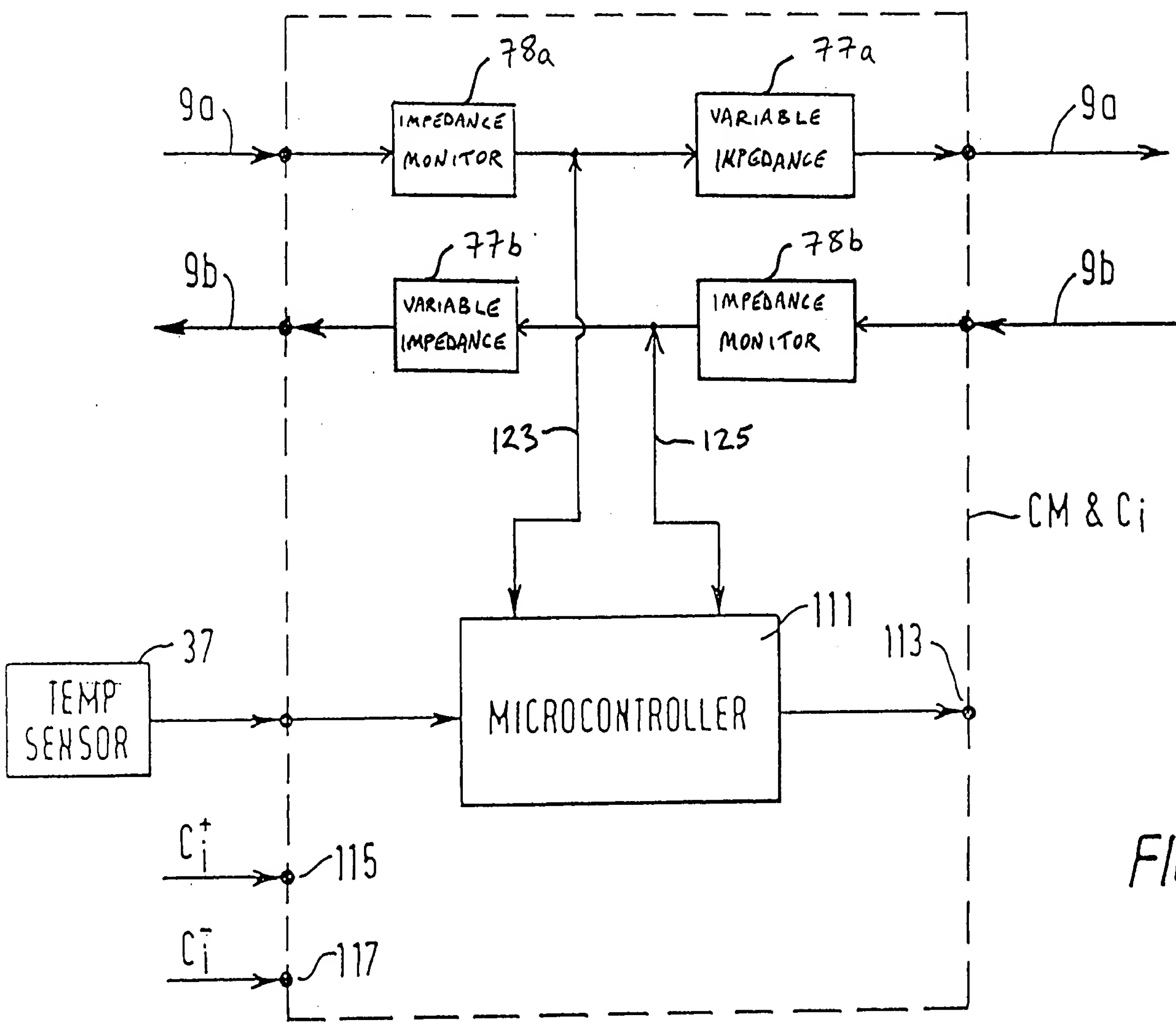

CC1
CC2
CC3
CC4
CC5
CCn
C_1^-
C_1^+
C_2^-
C_2^+
C_3^-
C_3^+
C_4^-
C_4^+
C_5^-
C_5^+
C_n^-
C_n^+
C_1
C_2
C_3
C_4
C_5
C_n
−
+
1
4
5
6
7
8
9
80
TEMP SENSOR
CENTRAL BATTERY CONTROL SYSTEM

8/11



9
CCi
77
VARIABLE IMPEDANCE
91
95
97
93
78
IMPEDANCE MONITOR
MICROCONTROLLER
81
83
9
39
ELECTROLYTE LEVEL/ PH SENSOR
C_i^+
C_i^-
103
WATER TANK
99
C_i
105
ACID TANK
101

FIG. 10



78a
IMPEDANCE MONITOR
77a
VARIABLE IMPEDANCE
9a
9a
77b
VARIABLE IMPEDANCE
78b
IMPEDANCE MONITOR
9b
9b
123
125
CM & Ci
111
37
TEMP SENSOR
MICROCONTROLLER
113
C_i^+
115
C_i^-
117

FIG. 11

FIG.12

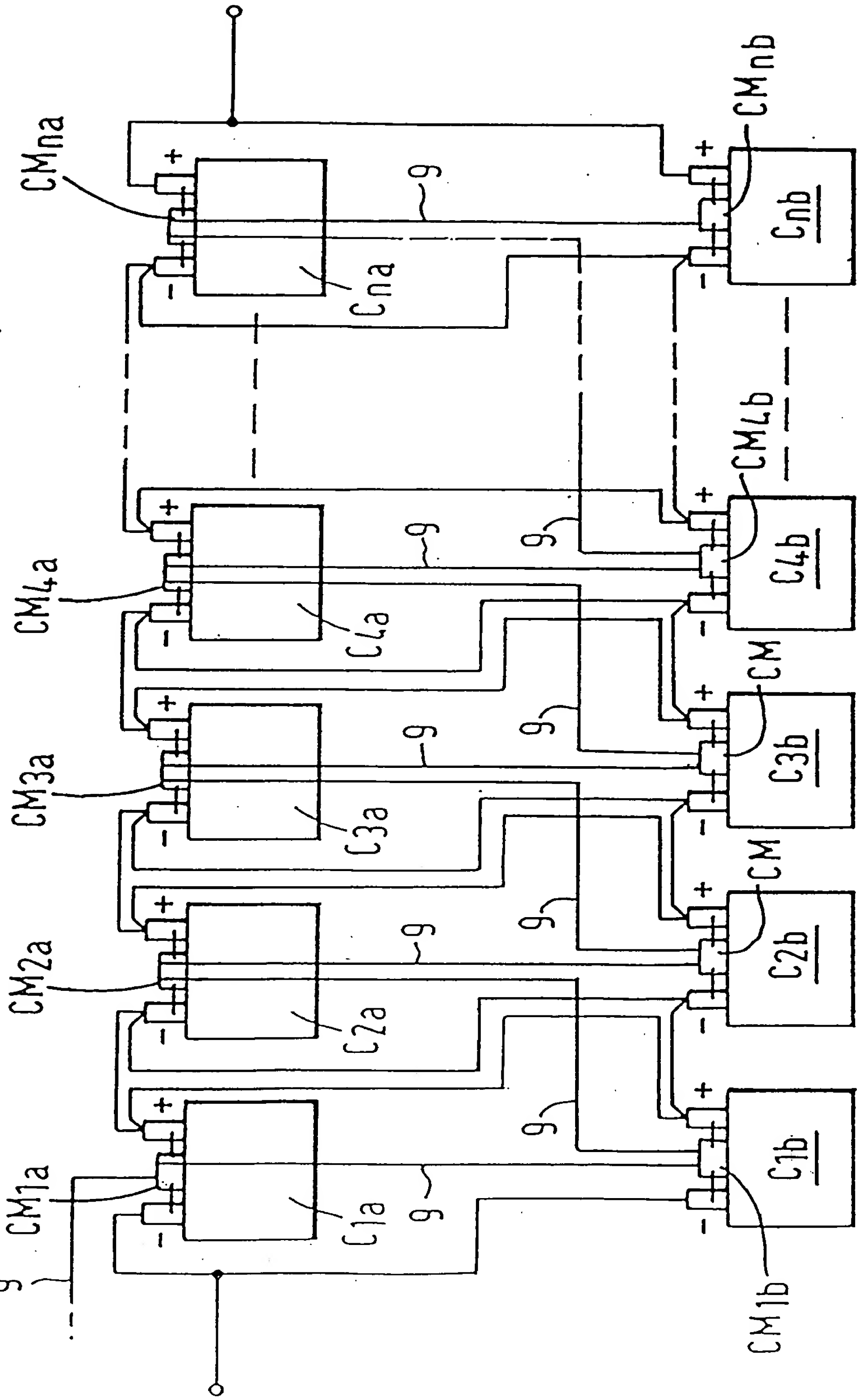
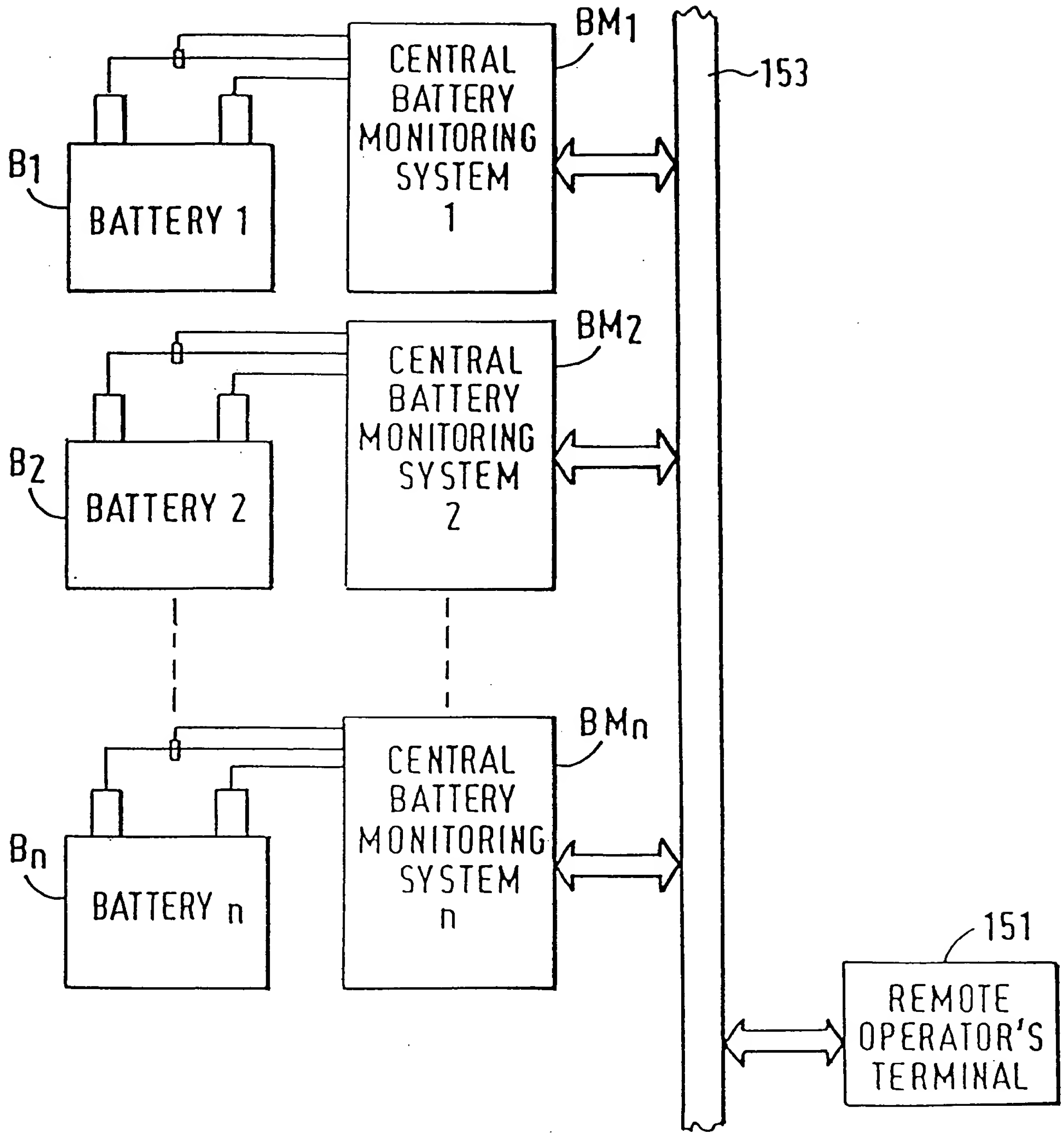

CM1a
CM2a
CM3a
CM4a
CMna
C1a
C2a
C3a
C4a
Cna
C1b
C2b
C3b
C4b
Cnb
CM1b
CM
CM
CM4b
CMnb
9
+
-

FIG. 13


BM1
153
CENTRAL BATTERY MONITORING SYSTEM 1
B1
BATTERY 1
BM2
CENTRAL BATTERY MONITORING SYSTEM 2
B2
BATTERY 2
BMn
CENTRAL BATTERY MONITORING SYSTEM n
Bn
BATTERY n
151
REMOTE OPERATOR'S TERMINAL